Music Informatics

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Today

- Xenakis on formalised music
- Shape by instrumental micro-structure
- Statistical distributions in music generation
- Graphical interface for composition

Xenakis

Iannis Xenakis (1922-2001) was a Greek composer and architect who was very influential on the innovative use of computers in musical composition.

After studying engineering in Greece, he worked for the architect le Corbusier in France; his music from then is influenced by architectural concepts and the use of computers to calculate how these effects could be achieved. He studied music with Messiaen, who did not ask him to study counterpoint or harmony:

> *No, you are almost thirty, you have the good fortune of being Greek, of being an architect and having studied special mathematics. Take advantage of these things. Do them in your music.*
>
> *Olivier Messiaen*
> *in Matossian, 1986, "Xenakis"*
> *London: Kahn and Averill*

Writings

Most of Xenakis's writings were originally in French, with translations in various languages:

- Musiques Formelles, 1962.
  (English version as Formalized Music, 1971, extended version 1991)
- Musique/Architecture, 1971 (some of this in English in Formalized Music;
  more recent collection in English, "Music and Architecture" 2008)
- Kéleütha, 1994

on-line:

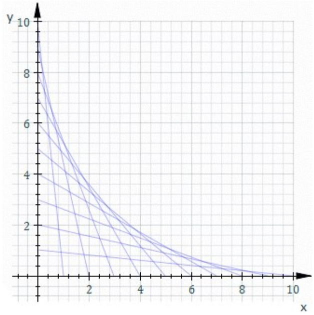
`http://www.iannis-xenakis.org`

Making curves out of straight lines

An early piece took ideas from the structuring of space and applied them to music.

> *We are surrounded by surfaces — plane, cylindrical, conic etc., made by humans or by nature (mountains, seas, clouds). This aspect of human understanding is . . . fundamental. [We know how to] define these surfaces from the basic spatial entity, the straight line. In music the most obvious straight line is the constant and continuous variation in pitch, the glissando.*
>
> *Xenakis, les 3 paraboles*

The envelope of a curve



A bunch of straight lines (all of the same length here) approximate a curve at the edge of the filled area – animated version on wikipedia:

`http://en.wikipedia.org/wiki/File:EnvelopeAnim.gif`

In Music: intermediate sketch

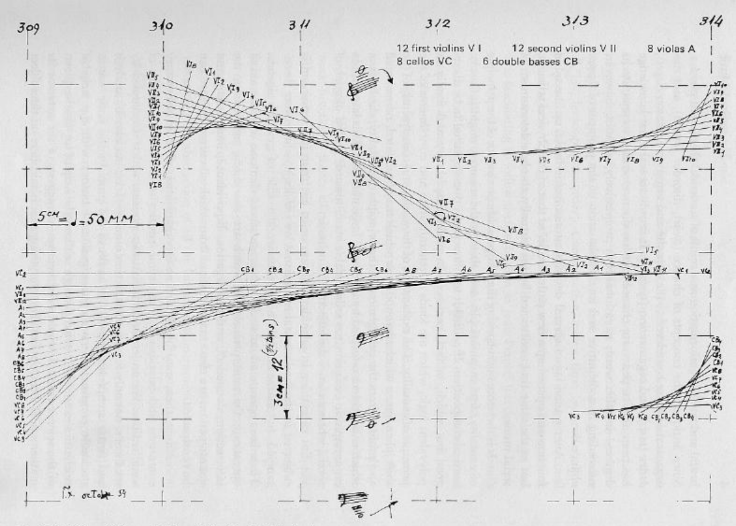


Fig. I–2. String Glissandi, Bars 309–14 of *Metastasis*

From sketch to score

In the sketch, the music is laid out as in a single left-to-right system of sound, with musical pitch as the vertical dimension; the pitch scale is indicated at the left, the temporal scale the top.

To have such sound performed by a classical orchestra, he needs to prescribe many individual glissandi, with precise starting and ending pitches, as well as starting and ending times.

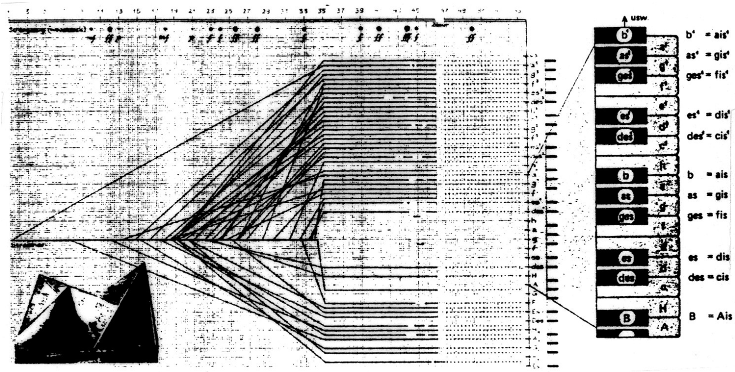
It is not easy to spot this passage in a recording —
it is just before the gap which precedes the final continuous passage, with a series of crescendos and diminuendos.

Opening glissandi

Also see the sketch for the very opening of the piece, which can be read in the same way. Here the single initial pitch splits apart slowly, not completely uniformly, into a sustained chord.
The next image shows early sketch for shows this splitting process.

There are some on-line performances.

Start Metastasis: sketch



Computers are good at producing (pseudo)-random numbers; this can be used to generate numbers according to a probability distribution.

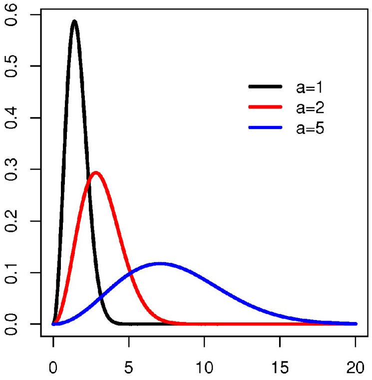
For example, the Maxwell-Boltzmann distribution of speeds of molecules in a gas; Xenakis used a version where a defines the "temperature" (amount of energy, higher speeds):

$$f(x) = \frac{2}{a\sqrt{\pi}}\ e^{-x^2/a^2}$$

where x measures the likelihood that a molecule has a certain (positive or negative) speed.

Examples

We can get a qualitative idea by considering possible curves, depending on *a* (this from wikipedia – x is on x-axis, f(x) on y axis)



Musical gas

Xenakis made music out of this distribution, with glissandi representing particles in motion.
The organisation in any section uses 3 hypotheses:

- Density of animated sound is constant –
  2 regions of equal extent on the pitch range have same average number of glissandi;
- The absolute value of speeds (of glissandi up/down) is spread uniformly in different registers;
- There is no privileged direction – equal number of sounds ascending and descending.

Analogy with physics of gases

The reasoning here is the same as that used to explain the Maxwell-Boltzmann distribution. If gas is in an enclosed area,

- the density will be the same everywhere (hypothesis 1, different areas are different parts of pitch space here)
- the temperature is uniform (speed of molecules = energy), and
- there is nothing special about any direction (in this case, just up/down).

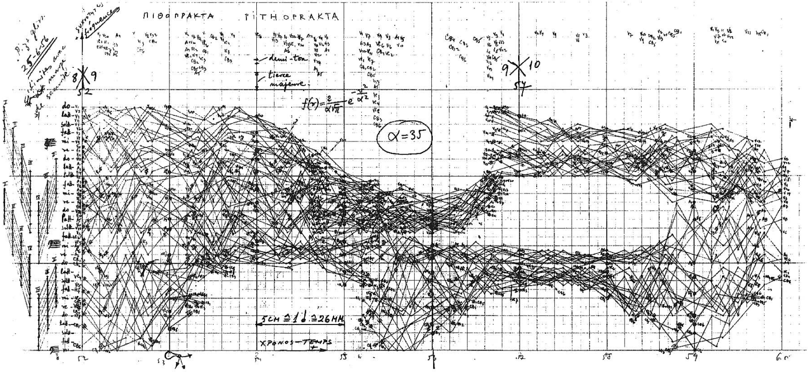
Xenakis was thus able to generate different textures (eg by varying temperature) but keeping the random character of the individual atom (= instrument = player). Different sections can have different characteristics, depending on the range of pitch space made available.

Random numbers generated following the distribution are used to select properties for individual instruments.
This is an important aspect of his piece Pithopratka.

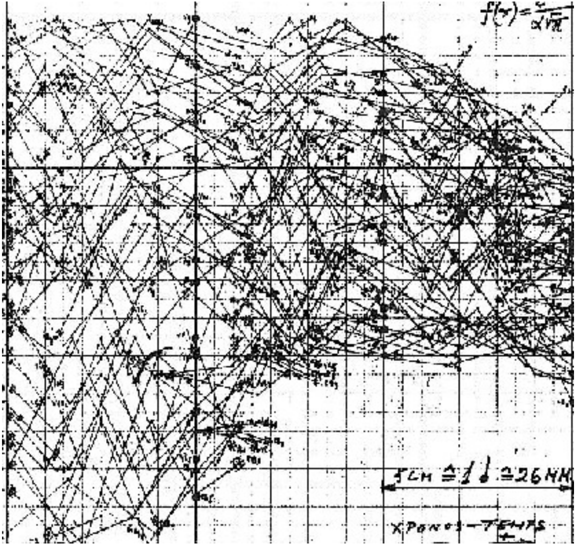
Pithopratka diagram

Pithoprakta (1955-56), mesures 52-59 : graphique de Xenakis

Source : Iannis Xenakis, *Musique. Architecture*, Tournai, Casterman, 1976, p. 167



Zoom in



The extract as it sounds

Here the glissandi are made on plucked sounds, so they fade way, and are not so easy to hear.

`http://www.youtube.com/watch?v=RC3XCfDBIK8`

The following is based on "The instrumental music of Iannis Xenakis" by Benoît Gibson, pp 75–79. This looks at Xenakis's use of Markov processes for composition, where the observed outputs themselves are generated probabilistically.

One thing that can be done with music, but not (easily) with natural language, is to make use of a simultaneous generation of of different paths through the Markov probability space, each generated according to associated transition probabilities.

In this particular case, there is a balance of hidden states that the mixture converges to. (This may or may not be apparent to listeners.)

The hidden states

We can think of this as a Markov process that deals with just 8 hidden states (A,B,C,. . . ,H). Each of the states is associated with combinations of (2 or 4) “clouds” of sounds, and with given densities and ranges.

$b''-a'''$	**ff**	**ff**	**pp**	**pp**				
$c'-b''$	**pp**	**pp**	**f**	**f**				
$d\flat'-c''$					**ff**	**ff**	**pp**	**pp**
$d-d'\flat$					**f**	**f**	**pp**	**pp**
$e,-d$	**pp**	**pp**	**f**	**f**				
$e,,-e,$	**f**	**f**	**pp**	**pp**				
State:	A	B	C	D	E	F	G	H

- First column is pitch interval (c' as middle C);
- Number of sounds per second:
  $= 9$, $= 3$, $= 1$

States

These states correspond to very short collections of sounds, corresponding to given densities and intensities of musical events, in the given pitch interval.

The music is played by 9 instruments, so 9 states "in action" at any time.

Now allow states to evolve probabilistically, by a given transition matrix:

	A	**B**	**C**	**D**	...
A	0.021	0.357	0.084	0.189	...
B	0.084	0.089	0.076	0.126	...
C	0.084	0.323	0.076	0.126	...
...	...				

The music is then laid out according to these criteria.

Example (bar 43, combination of D and H)

Comments

These works, although written some time ago, show the possibilities open when mathematical and algorithmic tools are brought to bear to find new ways of making music.
Here the composer uses probabilistic algorithmic means to transform musical material, at the specification level.

Xenakis was also responsible for the UPIC system that we saw earlier, that allows people (even non-musicians) to put together music in a graphical way. His diagrams were prepared by hand, before anything like UPIC was available.

Other proposals

Xenakis had many other proposals; the English "Formalized music" has several programs to perform the musical (statistical, transformational etc) operations he was interested in.

These include

- game theory in a "duel" between 2 orchestras;
- exploring the symmetries of geometrical shapes.

See his writings and listen to the compositions.

Visual compositional interface

The HighC system grew out of Xenakis's UPIC, itself influenced by experience of architectural design techniques.
It is easy to install to get a quick idea of what is involved:

`https://highc.org`

Summary

- Xenakis and mathematical/algorithmic ideas for composition;
- Creating musical curves from straight lines;
- Locally random textures;
- Use of stochastic methods in evolution of musical material.
- Visual compositional interface